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# *Declaration*

*I, Megumi Odawara, a translator of Fukuyama Sangyo Honyaku Center, Ltd., of 16-3, 2-chome, Nogami-cho, Fukuyama, Japan, do solemnly and sincerely declare that I understand well both the Japanese and English languages and that the attached document in English is a full and faithful translation, of the copy of Japanese Laid-open Patent No. Hei-6-154228 laid open on June 3, 1994.*

M. Odawara

*Megumi Odawara*

*Fukuyama Sangyo Honyaku Center, Ltd.*

Optical Tomographic Imaging Device

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Inventor: Mamoru KANEKO, et al.

Applicant: Olympus Optical Co., Ltd.

Patent Attorney: Susumu ITO

SPECIFICATION

[TITLE OF THE INVENTION] Optical Tomographic Imaging Device

[ABSTRACT]

[Object] To provide an optical tomographic imaging device by which the degree of infiltration at an affected portion can be easily measured.

[Composition] The image of the surface of affected portion 3 can be observed with the naked eye through colposcope 2, and in addition, the observable surface image is displayed on monitor 7 via TV camera 5. Also, low-interference light generated by SLD 31 is transmitted by optical fiber 33a, and emitted toward the affected portion 3 side via the optical system of colposcope 2 from scanner 21. Mirror 55 is moved to

change the optical path length, whereby a tomographic image in the direction of the depth of the affected portion 3 is obtained, outputted to the monitor 7 via superimposing circuit 18, and can be displayed together with the observable surface image.

[WHAT IS CLAIMED IS;]

[Claim 1] An optical tomographic imaging device comprising:

an image pickup means equipped with an illumination light emission means for emitting illumination light, an objective optical system for forming an image of the surface of an object to be examined which is illuminated by the illumination light, and an image pickup element for photoelectrically converting an image based on the objective optical system;

a low-interference light generation means for generating low-interference light;

a light guide member which guides the low-interference light into the image pickup means, emits the low-interference light from the end face at the front end side to the side of the object to be examined inside the image pickup means, and guides light reflected at the side of the object to be examined;

an interference light extraction means which makes the reflected light guided by the light guide member interfere with reference light generated from the low-interference light, and

extracts an interference signal corresponding to the interference light;

an optical path length changing means for changing the optical path length at the reference light side or the reflected light side;

a signal processing means which carries out signal processing for the interference signal to construct a tomographic image in the direction of the depth of the object to be examined; and

a display means for simultaneously displaying the image picked-up by the image pickup element and the tomographic image.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Field of the Invention] The present invention relates to an optical tomographic imaging device by which a tomographic image of an object to be examined is obtained by using low-interference light.

[0002]

[Prior Arts] Priorly, for diagnosis of uterine neck cancer, observation of the surface of the uterine neck was carried out by using a colposcope. By the colposcope, infiltration in the direction of the depth of an affected portion from the surface

of the uterine neck is presumed, or biopsy is carried out at a portion at which cancer most rapidly progresses, and a diagnosis is made by means of the diagnosis of tissue, whereby a cure method is determined.

[0003]

[Themes to be Solved by the Invention] However, in the abovementioned method, the rate of correct diagnosis is not good (depending on the skillfulness of the doctor and the portion for biopsy), and there are problems such that there is possibility that some portion is left untreated by means of transpiration and circular-excision by using a laser.

[0004] Furthermore, normally, tissue collection by means of biopsy is carried out for only one portion, and there is a possibility that the affected portion cannot be securely collected. In order to securely collect an affected portion, if tissue collection is carried out over a wide range, biopsy must be performed many times, or excision of a wide area becomes necessary, whereby the patient's pain increases.

[0005] The invention is made in view of the above circumstances, and the objet thereof is to provide an optical tomographic imaging device by which infiltration of an affected portion can be easily measured.

[0006]

[Means for Solving Themes] An image pickup means equipped with an illumination light emission means for emitting illumination light, an objective optical system for forming an image of the surface of an object to be examined which is illuminated by the illumination light, and an image pickup element for photoelectrically converting an image based on the objective optical system, a low-interference light generation means for generating low-interference light, a light guide member which guides the low-interference light into the image pickup means, emits the low-interference light from the end face at the front end side to the side of the object to be examined inside the image pickup means, and guides light reflected at the side of the object to be examined, an interference light extraction means which makes the reflected light guided by the light guide member interfere with reference light generated from the low-interference light, and extracts an interference signal corresponding to the interference light, an optical path length changing means for changing the optical path length at the reference light side or the reflected light side, a signal processing means which carries out signal processing for the interference signal to construct a tomographic image in the direction of the depth of the object to be examined, and a display means for simultaneously displaying the image

picked-up by the image pickup element and the tomographic image are provided, whereby, at the same time of observation of the surface image picked-up by the image pickup means, a tomographic image at the same portion can be obtained, and therefore, the range of an affected portion can be easily determined from this tomographic image.

[0007] Therefore, there is a case where biopsy is not necessary, however, even in the case where biopsy is carried out, the portion which needs biopsy is minimum, and the patient's pain can be significantly reduced. In addition, the burden on the operator is also reduced.

[0008]

[Preferred Embodiments] Hereinafter, embodiments of the invention shall be described with reference to the drawings. Fig. 1 through Fig. 3 relate to the first embodiment of the invention, wherein Fig. 1 shows the optical tomographic imaging device of the first embodiment, Fig. 2 shows the construction of the scanner, and Fig. 3 shows that a tomographic image is shown on the monitor together with the image of an affected portion.

[0009] This optical tomographic imaging device 1 of the first embodiment is comprised of colposcope 2 by which affected portion 3 such as an uterine neck cancer inside a living body

can be observed, optical tomographic observation device 4 which generates low-interference light and guides it to the colposcope 2 side for optical tomographic imaging and then makes light reflected from the affected portion 3 side interfere with reference light to detect it, signal processing device 6 which carries out signal-processing for the interference signal detected by the observation device 4 and TV camera 5 mounted to the colposcope 2, and monitor 7 for displaying an image signal outputted from the signal processing device 6, wherein an observable (surface) image of the affected portion 3 obtained by the TV camera 5 and an optical tomographic image by means of the low-interference light are superimposed and displayed on the monitor 7.

[0010] The abovementioned colposcope 2 is binocular, and in order to form an optical image of the affected portion 3 illuminated by illumination light from an unillustrated illumination means, at the front end of lens barrel 8, common objective lens 11 with a large diameter is attached, and variable magnification lenses 12a and 12b, beam splitters 13a and 13b, image forming lenses 14a and 14b, and eyepieces 15a and 15b are disposed along the optical axis so as to be opposite to the objective lens 11.

[0011] The images of the light beams after being split by the

beam splitter 13a are formed on an unillustrated CCD of the TV camera 5 through the image forming lens 16. The output signal of this TV camera 5 is inputted into the image signal processing circuit 17, an image signal is generated and mixed with an image signal passed through calculation device 19 from the optical tomographic image observation device 4 side by superimposing circuit 18, and then outputted to the monitor 7 and displayed on the monitor 7 as shown in Fig. 3(b), for example.

[0012] Onto another beam splitter 13b, light from the optical tomographic image observation device 4 side through the scanner 21 is made incident, and light reflected at the affected portion 3 side is guided to the optical tomographic image observation device 4 side via the beam splitter 13b. This scanner 21 causes low-interference light to scan in a two-dimensional manner by 2-axis controller 22.

[0013] Inside the optical tomographic image observation device 4, super-high brightness light emitting diode (hereinafter, abbreviated to SLD) 31 is disposed as a light source to generate low-interference light. This SLD 31 emits light with a wavelength of 830nm and an allowable interference distance of approximately several tens through several thousand μm, for example, and this light passes through the lens 32a, polarizer 32b, and lens 32c, and then is converted into straight polarized

light by a predetermined polarization surface, made incident from one end face of single mode optical fiber 33a, and transmitted to the other end face side (front end surface).

[0014] This optical fiber 33a is optically coupled with another single mode optical fiber 33b by PANDA coupler 34 at the middle. Therefore, at this coupler 34, light is split and transmitted. The front end side (from the coupler 34) of the optical fiber 33a is wound around a piezoelectric element such as zirconic acid lead ceramics (abbreviated to PZT) 35.

[0015] A drive signal is applied to the PZT 35 from oscillator 36 to vibrate the optical fiber 33a, whereby the PZT forms modulator 37 for modulating transmitted light. The frequency of this drive signal is, for example, 5 to 20KHz. The modulated light exits from the front end face of the optical fiber 33 toward the scanner 21.

[0016] As shown in Fig. 2, at the scanner 21, light converging lens 38 is disposed so as to be opposite to the front end face of the optical fiber 33a, and the light is made incident onto mirror 39 through the light converging lens 38. This mirror 39 is attached to the shaft of first gear box 41b provided on the shaft of first motor 41a, and the mirror 39 is rotated as shown by the arrow Y1 in accordance with the rotation of the first motor 41a controlled by the 2-axis controller 22.

[0017] In addition, the first motor 41 and first gear box 41b are supported by supporting member 41c, and this supporting member 41c is attached to the shaft of second gear box 41d which is disposed so as to be orthogonal to the shaft of the first motor 41a. This second gear box 41d is provided on the shaft of second motor 41e.

[0018] When the second motor 41e which is controlled by the 2-axis controller 22 is rotated, the mirror 39 is rotated as shown by the arrow Y2. By the rotation of the mirror 39 as shown by the arrows Y1 and Y2, light which is caused to two-dimensionally scan toward the beam splitter 13b side is guided, and the light reflected from the beam splitter 13b side is guided to the front end face of the optical fiber 33a.

[0019] As shown in Fig. 1, the light guided toward the beam splitter 13b side is emitted toward the affected portion 3 side via the variable magnification lens 12b and objective lens 11, and then two-dimensionally scans the affected portion 3, and a part of the light reflected by the inside tissue at the affected portion 3 is guided to the front end face of the optical fiber 33a through the beam splitter 13b.

[0020] Nearly the half of this light transfers to the optical fiber 33b at the coupler 34, and is guided to the interference light detector 44. Also, the optical fiber 33b also transmits

the light reflected by the mirror 45 attached to the front end face of the fiber (reference light split at the coupler 34 from the light from the SLD 31 side), and guides it to the interference light detector 44. That is, the light to be guided toward the interference light detector 44 side is transmitted to the optical fiber 33a side, and the measurement light reflected from the affected portion 3 is mixed with the reference light reflected by the mirror 45.

[0021] In addition, between the front end part to which the mirror 45 is fixed of the optical fiber 33b and the coupler 34, compensation ring 46 is provided to roughly compensate for the optical path length of the optical fiber 33a around the modulator 37 and optical path length reaching the affected portion 3 side. Light emitted from the rear end face of the optical fiber 33b is collimated by lens 47, and the light component of the abovementioned polarization surface is extracted by analyzer 48, and then split into transmitted light and reflected light by the half mirror 49.

[0022] The reflected light is reflected by the mirror 51, (the light component further transmitted by the half mirror 49) is converged by the lens 52, and received by photodiode (abbreviated to PD) 53 as a photodetector. The light transmitted through the half mirror 49 is reflected by mirror

55 attached to X-stage 54, and (the light component reflected by the half mirror 49) is converged by the lens 52 and received by the PD 53. The X-stage 54 is moved in the direction X opposite to the end face of the optical fiber 33b by, for example, stepping motor 56 to change the optical path length.

[0023] In the case of obtaining a tomographic image of the affected portion 3, the optical path length until the light reflected by the mirror 45 and 55 is made incident onto the PD 53 and the optical path length until the light returned from the affected portion 3 side through the optical fiber 33a is reflected by the mirror 51 and made incident on the PD 53 are set to be almost equal to each other.

[0024] In other words, the position of the mirror 55 changes to change the optical path length at the reference light side, whereby the optical path length at the measurement light side which is equal to the optical path length at reference light side is changed in the direction of the depth of the affected portion 3. Then, these two light rays having optical path lengths equal to each other interfere with each other, and are detected by the PD 53.

[0025] Furthermore, the optical path length from the half mirror 49 to the mirror 51 and the optical path length from the half mirror 49 to the mirror 55 is set so as to always deviate

from at least the interference range of low-interference light, in order to prevent interference, for example, in the case where light to be measured is split into transmitted light and reflected light by the half mirror 49 and then mixed by the half mirror 49.

[0026] In accordance with the signal which is photoelectrically converted by the PD 53, a drive signal for the oscillator 36 or a signal with the same phase as that of the drive signal is inputted together with a reference signal into an unillustrated lock-in amplifier of the calculation device 19 which comprises the signal processing device 6, and heterodyne-detected whereby a signal component with the same frequency as that of the reference signal is extracted from the signal from the PD 53, and the signal component with the same phase is extracted, and further detected and amplified, and thereafter, inputted into an unillustrated computer unit inside the calculation device 19.

[0027] In this computer unit, based on coordinate data specified by the mouse 57 and a magnification signal inputted from magnification detector circuit 58, as shown in Fig. 3(a), the coordinates in the range of the cursor K to be superimposed with a scope image G1 obtained by the colposcope 2 displayed on the monitor 7 are calculated.

[0028] From the calculation result of the coordinates, the amount of rotation of the motors 41a and 41e of the scanner 21 are determined, and the motors are driven to rotate via the 2-axis controller 22, and the range specified by the mouse 57 is optically scanned by light. A signal obtained by light scanning is temporarily stored in an unillustrated image memory, and by the scanning of the mirror 55 in accordance with the rotation of the motor 56, a scanned image of a predetermined range in the direction of the depth is obtained. Then, the image data of the image memory is converted into an image signal corresponding to an optical tomographic image by the image signal processor, and outputted to the monitor 7 via the superimposing circuit 18.

[0029] In this embodiment, when an image signal corresponding to an optical tomographic image is outputted from the calculation device 19 side, the scope image G1 picked-up by the TV camera 5 is reduced, and displayed at the same time as the optical tomographic image G2 as shown in Fig. 3(b).

[0030] According to this embodiment, since the scope image G1 and tomographic image G2 of the surface of the affected portion 3 such as the uterine neck can be simultaneously displayed on the monitor 7, the affected portion and the range of spread of the affected portion in the direction of the depth can be

grasped from the tomographic image G2. Accordingly, without the necessity of a plurality of biopsies, the range in the direction of the depth of the affected portion can be judged. Therefore, the patient's pain can be reduced (since it is not necessary that biopsy is carried out a plurality of times), and the burden on the operator can also be reduced.

[0031] Furthermore, by the optical fiber 33a, light is guided to the colposcope 2 via the scanner 21, so that the lens barrel 8 portion can be reduced in diameter. Moreover, since light is guided to the beam splitter 13b, the beam splitter 13b can be arranged as an attachable and detachable unit. If this arrangement is employed, in the case where the colposcope 2 is used, the unit for obtaining an optical tomographic image can be selected to be used or not be used as necessary.

[0032] Fig. 4 shows TV probe 61 in a modified example of the first embodiment. In this modified example, in place of the colposcope 2 of Fig. 1, the TV probe 61 with CCD 62 installed is used.

[0033] In this TV probe 61, objective lens 64, variable magnification lens 65, dichroic mirror 66, image forming lens 67, and CCD 62 are disposed in order in a cylindrical probe main body 63, and a signal of the CCD 62 is inputted into the image signal processing circuit 17. In addition, scanner 21

is attached to the reflected light path side of the dichroic mirror 66, and the light of the optical fiber 33a is guided to the dichroic mirror 66 side, and the light from the dichroic mirror 66 side is guided to the optical fiber 33a side.

[0034] As shown in Fig. 5, a mirror to be used as dichroic mirror 66 has wavelength reflectance properties by which 100% of light from the boundary wavelength between the visible range and near-infrared range to the side of the near-infrared range is reflected, and roughly 100% of light in the visible range is transmitted. The wavelength of SLD 31 is set within the infrared range, whereby the light is always reflected by the dichroic mirror 66, and has no influence on the CCD 62 which picks up an image by means of the light in the visible range.

[0035] That is, light from the optical fiber 33a is reflected by the dichroic mirror 66 and guided to the objective lens 64 side, and light reflected by the SLD 31 to return to the dichroic mirror 66 from the objective lens 64 side is reflected by the dichroic mirror 66 and guided to the optical fiber 33a side. On the other hand, light in the visible range is transmitted through the dichroic mirror 66 and the image thereof is formed on the CCD 62.

[0036] Other arrangements are the same as in the first embodiment. In this modified example, without the observation

optical system for the naked eye with use of colposcope 2 of the first embodiment, an image displayed on the monitor 7 is observed. Fig. 6 shows the image G displayed on the monitor 7 which is picked-up by the CCD 62. At only the portion which is determined in advance on the monitor 7 (at the index S at the center in this modified example), a tomographic image can be observed.

[0037] Therefore, the operator moves and sets the TV probe 61 so that a desired portion to be observed is positioned at the center. The range of tomographic image can be set in a changeable manner within the scanning range of the 2-axis controller 21. Furthermore, as shown in Fig. 7, in front of the objective lens 64 of Fig. 4, ring-shaped rubber 69 is attached, whereby the front end of the probe is pressed against a portion which can be contacted with the uterine neck to obtain an optical tomographic image.

[0038] Fig. 8 shows optical tomographic imaging device 71 of the second embodiment of the invention. This optical tomographic imaging device 71 of the second embodiment is comprised of endoscope 72 by which an optional portion inside a body cavity can be observed, a light source device 73 for supplying illumination light to the endoscope 72, a light interference device 74 to which a light guide member provided

inside the endoscope 72 for guiding low-interference light is connected for optical tomographic imaging, and monitor 75 as a display device for displaying an optical tomographic image by means of the light interference device 74.

[0039] The light interference device 74 is comprised of light interference part 76 for obtaining an electric signal corresponding to low-interference light to generate an optical tomographic image by using the low-interference light, and signal processor 77 for generating an image signal corresponding to an optical tomographic image by processing the electric signal of the light interference part 76, and the image signal is displayed on the monitor 75.

[0040] The abovementioned endoscope 72 has insertable part 78, which is thin and long and has flexibility, and thick manipulation part 79, which is provided at the rear end of the insertable part 78, and a cable is extended from the side of the manipulation part 79 to the outside.

[0041] Inside the insertable part 78, light guide 81 is inserted, and a connector provided at the end part of the cable side of the light guide 81 can be detachably attached to the light source device 73. By this attachment, inside the light source device 73, for example, white illumination light of xenon lamp 82 is converged by the condenser lens 83 and supplied to the

end part of the light guide 81, and this illumination light is transmitted by the light guide 81, and emitted to the side of the insertable part 78 from the other end face fixed to the illumination window provided at the side part of the front end part 84 of the insertable part 78.

[0042] An optical image of a portion to be observed such as duct organ 85 illuminated by the illumination light emitted from the illumination window for side vision is formed at the focus plane by the objective lens 86 attached to the observation window for side vision adjacent to the illumination window. At the position of this focus plane, CCD 87 is disposed to photoelectrically convert the optical image.

[0043] A CCD drive signal is applied to the CCD 87 from CCD drive circuit 88, whereby the photoelectrically-converted signal is read-out, and inputted into video processor (hereinafter, abbreviated to VP) 90 as an image signal processing means via video signal line 89.

[0044] The output signal of the VP 90 is outputted to the monitor 75 via superimposing circuit 91, whereby an endoscope image picked-up by the CCD 87 is displayed thereon.

[0045] In addition, an unillustrated bending manipulation mechanism is provided in the manipulation part 79, and by manipulating a bending manipulation knob, the bendable portion

formed at the rear end of the front end part 84 can be bent optionally in both a vertical or horizontal direction. Into this endoscope 72, optical fiber 92 for transmitting low-interference light is further inserted.

[0046] The front end of this optical fiber 92 is fixed on the center axis of the front end part 84, and at the front end surface, refractive index profile type lens (hereinafter, referred to as SELFOC lens) 93 is attached. The rear end side of this optical fiber 92 is connected to the front end face of the optical fiber 33a of the light interference part 76, and light of the SLD 31 is guided through this optical fiber 33a.

[0047] Light of the SLD 31 is made incident from one end face of the single mode optical fiber 33a via the lens 32, and transmitted to the other end face side. This optical fiber 33a is optically coupled with the other single mode optical fiber 33b by the coupler 34. Therefore, the light is split into two at this coupler 34 part and transmitted. The front end side (from the coupler 34) of the optical fiber 33a is wound around the piezoelectric element such as PZT 35.

[0048] This PZT 35 forms modulator 37 which modulates the transmitted light by vibrating the optical fiber 33a when a drive signal is applied from the oscillator 36. The modulated

light is emitted from the front end face of the optical fiber 33a and made incident onto the optical fiber 92 contacted with the front end face of the fiber 33a, transmitted to the end face of the front end part 84 side, and emitted from this end face via the SELFOC lens 93.

[0049] The light is converted into a parallel light beam by lens 94 disposed opposite to the SELFOC lens 93, reflected by the inclined plane of the prism 96 attached to gear 95, and emitted toward the side of the insertable part 78. This gear 95 is provided with an opening so as to transmit light at the center part. This gear 95 is engaged with gear 97a attached to the rotation shaft of motor 97.

[0050] Therefore, when the motor 97 rotates, the prism 96 is rotated, and the light guided by the optical fiber 92 is radially emitted around the center axis of the insertable portion 78.

[0051] Furthermore, this motor 97 is fixed to motor fixing base 98 having a rack formed on the back. This rack is engaged with pinion gear 99a attached to the rotation shaft of the motor 99.

[0052] When the motor 99 rotates, the rack moves, and the motor 97 fixed to the motor fixing base 98, gear 97a attached to the rotation shaft of the motor, and the gear 95 which maintains

the engaged condition with the gear 97a are interlocked with each other and move in the axis direction of the insertable part 78, that is, the length direction. The amount of rotation of these motors 97 and 99 is controlled by position controller 101 inside the signal processor 77.

[0053] The light reflected by the duct organ 85 is made incident onto the front end face of the optical fiber 92 through the prism 96, lens 94, SELFOC lens 93, and then made incident onto the front end face of the optical optical fiber 33a from the rear end face of the optical fiber 92a. Almost the half of this light is transferred to the optical fiber 33b by the coupler 34, and guided to the interference light detector side together with reference light reflected by the mirror 45 which is disposed opposite to the front end face of the optical fiber 33b.

[0054] In the first embodiment, an optical path length changing mechanism for changing the optical path length of the reference light is provided at the interference light detector side, however, in this embodiment, the optical path length changing mechanism is provided at the front end face of the optical fiber 33b.

[0055] In other words, the mirror 45 in the embodiment of Fig. 1 is attached to the X-stage 54, and is moved by the motor 56

to change the optical path length of the reference light, whereby the optical path length is changed. Lens 45a is disposed between the front end face of the optical fiber 33b and mirror 45. The rotation of the motor 56 is controlled by the position controller 101.

[0056] Light emitted from the rear end face of the optical fiber 33b is received by the PD 53 through the lens 52. The signal which is photoelectrically converted by the PD 53 is amplified by the pre-amplifier 102, and then inputted to the signal input terminal of the lock-in amplifier 103 of the signal processor 77. At the reference signal input terminal of the lock-in amplifier 103, a reference signal is inputted from the oscillator 36, and heterodyne-detected and amplified.

[0057] The output of the lock-in amplifier 103 is inputted to computer 105 via digital volt meter (hereinafter, abbreviated to DVM) 104 to carry out control for generating image data corresponding to a tomographic image from the signal obtained by the light guided by the optical fiber 92.

[0058] In other words, a control signal is sent to the position controller 101 to control the amount of rotation of the motors 97 and 99, whereby scanning of the light beam and the change in optical path length due to control of the rotation of the motor 56 are controlled. In scanning of the light beam and

change in the optical path length, a signal obtained from the PD 53 is temporarily stored in the image memory.

[0059] For example, when image data corresponding to one frame is obtained, the data is outputted to the VP 106, and the VP 106 converts it into an image signal, and outputs it to the monitor 75 via the superimpose circuit 91, and then the signal is superimposed with the image of CCD 87, whereby an optical tomographic image is displayed.

[0060] In addition, in the case where the motor 99 is rotated to move the prism 96 in the length direction, since the optical path length at the measurement light side changes due to this movement, a control signal is sent to the position controller to rotate the motor 56, whereby control is made so as to compensate for the change in the optical path length. By this control, distortion of the image due to the change in the optical path length is corrected. This embodiment has merits whereby the effect of the first embodiment is obtained, and in addition, a three-dimensional tomographic image can be obtained.

[0061] Fig. 9 shows the optical tomographic imaging device 111 of the third embodiment. This optical tomographic imaging device 111 of the third embodiment is comprised of endoscope 112 by which an optional portion inside a body cavity can be

observed, light source device 73 for supplying illumination light to the endoscope 112, light interference device 114 to which a light guide member provided inside the endoscope 112 for guiding low-interference light is connected, and which generates light for optical tomographic imaging and detects interference light, signal processor 115 for carrying out signal processing to generate an image signal corresponding to an optical tomographic image in accordance with the signal from the optical interference device 114, and a monitor 116 as a display device for displaying the image signal outputted from the signal processor 115.

[0062] In this third embodiment, by using dichroic mirror 117, a tomographic image of living body tissue 118 in the field of view of observation by the endoscope is obtained.

[0063] In the endoscope 112, as in the second embodiment, light guide 81 is inserted into the insertable part 78, and illumination light of the lamp 82 of the light source device 73 is transmitted to illuminate the living body tissue 118 side at the front side from the front end face fixed to the front end part 84 through glass plate 119 attached to the illumination and observation window. In this embodiment, the front end side of the light guide 81 is branched into two.

[0064] Inside the glass plate 119, objective lens 86 is disposed

to form an image at the CCD 87. This CCD 87 is driven by CCD drive circuit 88, and the signal which is photoelectrically converted is inputted into the VP 90 inside the signal processor 115 via video signal line 89, and the image signal outputted from this VP 90 is inputted into the monitor 116 via the superimposing circuit 91, whereby an (endoscope) image of the living tissue 118 is displayed on the left side of the monitor 116 as shown in Fig. 10.

[0065] Between the objective lens 86 and CCD 87, dichroic mirror 117 inclined by 45° from the optical axis of the objective lens 86 is provided. This dichroic mirror 17 has characteristics as shown in Fig. 5, which transmits light in the visible range and reflects light in the near-infrared range. On the reflection optical path of the dichroic mirror 117, prism 121 is disposed.

[0066] This prism 121 is attached to movable base 122 with a rack formed on the back. To this movable base 122, the front end of the optical fiber 92 is attached by an optical fiber fixing member, whereby light emitted from the front end face of the optical fiber 92 is reflected by the prism 121 and guided to the dichroic mirror 117 side, and the light reflected by the dichroic mirror 117 is reflected by this prism 121 and guided so as to be made incident onto the front end face of

the optical fiber 92.

[0067] The rack of the movable base 122 engages with pinion gear 125 attached to the front end of shaft 124 which is connected to the rotation shaft of stepping motor 123 housed in the manipulation part 79, for example, and by the rotation of the stepping motor 123, the movable base 122 is moved in the direction parallel to the optical axis of the objective lens 86, that is, the length direction of the insertable part 78.

[0068] For example, when the movable base 122 is moved rearward from the condition of Fig. 9, the prism 121 is also moved rearward, so that the light reflected by this prism 121 is guided as shown by the dotted line. Therefore, by moving the prism 121, light is caused to scan the living body tissue 118 side in the vertical direction, whereby a tomographic image corresponding to this scanning direction can be obtained.

[0069] The rear end of the optical fiber 92 is connected to the front end face of the optical fiber 33a of the light interference device 114, whereby low-interference light from the SLD 31 is guided to the optical fiber 92 side, and the light reflected from the optical fiber 92 side is guided to the optical fiber 33a side.

[0070] In the light interference device 114, the output of the

PD 53 is inputted into the lock-in amplifier 103, and a signal component of the same phase as that of the reference signal is extracted, detected, and inputted into the computer 126 inside the signal processor 115.

[0071] This computer 126 controls the rotation of the stepping motor 123 and the rotation of the motor 56. Furthermore, the computer carries out processing to generate an image signal corresponding to a tomographic image, and outputs the signal to the superimposing circuit 91, whereby a tomographic image is displayed on the monitor 116 together with the adjacent endoscope image as shown in Fig. 10.

[0072] Furthermore, the computer 126 displays cursor 128 indicating the range for measurement of the tomographic image within the endoscope image as shown in Fig. 10. By means of this display, the range in which a tomographic image is obtained can be recognized on the observed image, and this is convenient for diagnosis. This display of cursor 128 can be turned off when it is not necessary. In the construction of the light interference device 114, the same components as in the light interference part 76 shown in Fig. 8 are attached with the same symbols, and description thereof is omitted.

[0073] In this embodiment, at the front end face of the endoscope 112, glass plate 119, from which visible illumination

light exits and which takes-in visible observation light, is provided, and as shown in Fig. 11, in the condition where the front end face of the insertable part 78 is pressed against the tissue inside a living body such as stomach inner wall 129, an observable image can be obtained.

[0074] In addition, in the condition where the abovementioned front end is closely adhered to the tissue inside a body cavity, low-interference light for obtaining an optical tomographic image is emitted through the glass plate 119, and the light reflected from the tissue inside the body cavity is taken-in, whereby a tomographic image of the center part of the tissue inside the body cavity within the visible field of view can be obtained. By this close-adhesion, shake which may occur when the organ works or the front end of the insertable part 78 is unstable can be prevented, whereby unblurred and clear observable images and tomographic images can be obtained. Therefore, in this embodiment, the focal length of the observation system is set so as to be roughly suitable for observation at the surface of the glass plate 119. In addition, the optical fiber 92 to be inserted into the endoscope 112 and the optical fiber 33a of the light interference device 114 can be united together.

[0075] Fig. 12 shows the optical tomographic imaging device

131 of the fourth embodiment of the invention. The endoscope 132 in the fourth embodiment is arranged so that the front end face of the image guide 133 is disposed at the photoelectric conversion surface of the CCD 87, image forming lens 134 is disposed opposite to the rear end face of the image guide 133, and an image transmitted by the image guide 133 is formed by the image forming lens 134 at the CCD 87 disposed at the image forming position of the image forming lens.

[0076] In this embodiment, image guide 133 is inserted inside the insertable part 78, an observable image is transmitted to the rear end face of the manipulation part 79 side and formed at the CCD 87 by the lens 134. Other arrangements are the same as those described in the third embodiment. Furthermore, in this embodiment, the endoscope image displayed on the monitor 116 is round. The action and effect of this embodiment is almost the same as those of the third embodiment. In addition, in the case where the optical path length is changed, not only the optical path length at the reference light (standard light) side but also the optical path length of the measurement light side can be changed. In the case where the image is of the surface of a body to be examined, for example, a living body to be examined, the image is not limited to an image of visible light, but can be an infrared or ultraviolet image.

[0077]

[Effect of the Invention] As described above, according to the invention, since a observable surface image of visible light and a tomographic image of low-interference light of a body to be examined can be simultaneously displayed, the range of the affected tissue in the direction of the depth can be easily judged.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] Fig. 1 is a constructional view showing the optical tomographic imaging device of the first embodiment of the invention.

[Fig. 2] Fig. 2 is a perspective view showing the arrangement of the scanner.

[Fig. 3] Fig. 3 is an explanatory view showing that the monitor displays a tomographic image together with an image of an affected portion.

[Fig. 4] Fig. 4 is a drawing showing the TV probe in the modified example of the first embodiment.

[Fig. 5] Fig. 5 is a property diagram showing the spectrum properties of the dichroic mirror.

[Fig. 6] Fig. 6 is a drawing showing that an index corresponding to the range in which a tomographic image can be obtained is displayed on the monitor screen.

[Fig. 7] Fig. 7 is a sectional view showing the front end side of the TV probe in the modified example of Fig. 6.

[Fig. 8] Fig. 8 is a constructional view showing the optical tomographic imaging device of the second embodiment of the invention.

[Fig. 9] Fig. 9 is a constructional view showing the optical tomographic imaging device of the third embodiment of the invention.

[Fig. 10] Fig. 10 is a drawing showing the image display example of the monitor.

[Fig. 11] Fig. 11 is a drawing showing that observation is possible in the condition where the front end face of the insertable part is pressed against the tissue inside a body cavity.

[Fig. 12] Fig. 12 is a constructional view showing the optical tomographic imaging device of the fourth embodiment of the invention.

[Description of Symbols]

1 ··· optical tomographic imaging device

2 ··· colposcope

3 ··· affected portion

4 ··· optical tomographic image observation device

5 ··· TV camera

6 ··· signal processor

7 ··· monitor

8 ··· lens barrel

11 ··· objective lens

12a, 12b ··· variable magnification lens

13a, 13b ··· beam splitter

15a, 15b ··· eyepiece

17 ··· image signal processing circuit

18 ··· superimposing circuit

19 ··· calculation device

21 ··· scanner

22 ··· 2-axis controller

31 ··· SLD

32b ··· analyzer

33a, 33b ··· optical fiber

34 ··· coupler

35 ··· PZT

36 ··· oscillator

37 ··· modulator

39 ··· mirror

41a, 41e ··· motor

44 ··· interference light detector

48 ··· analyzer

49 ··· half mirror

51, 55 ··· mirror

53 ··· PD

54 ··· X-stage

56 ··· stepping motor

Fig.2

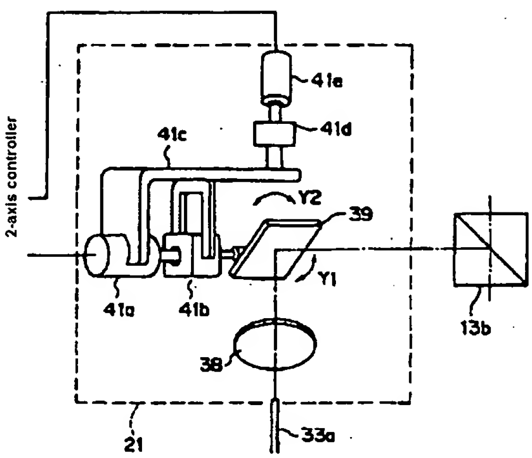



Fig.3

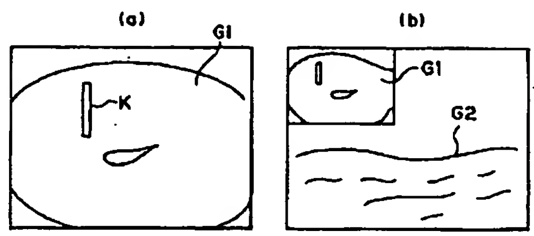



Fig.4

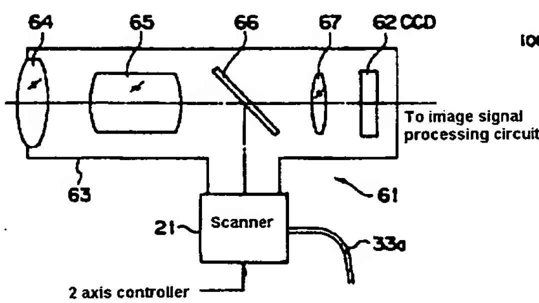



Fig.5

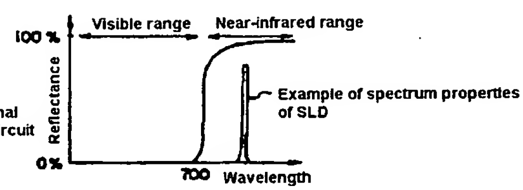



Fig.10

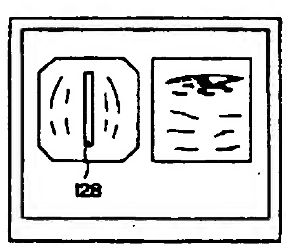



Fig.6

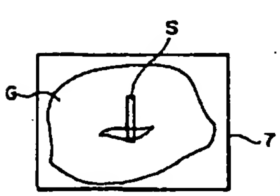



Fig.7

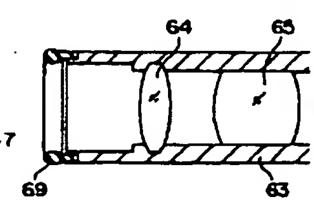
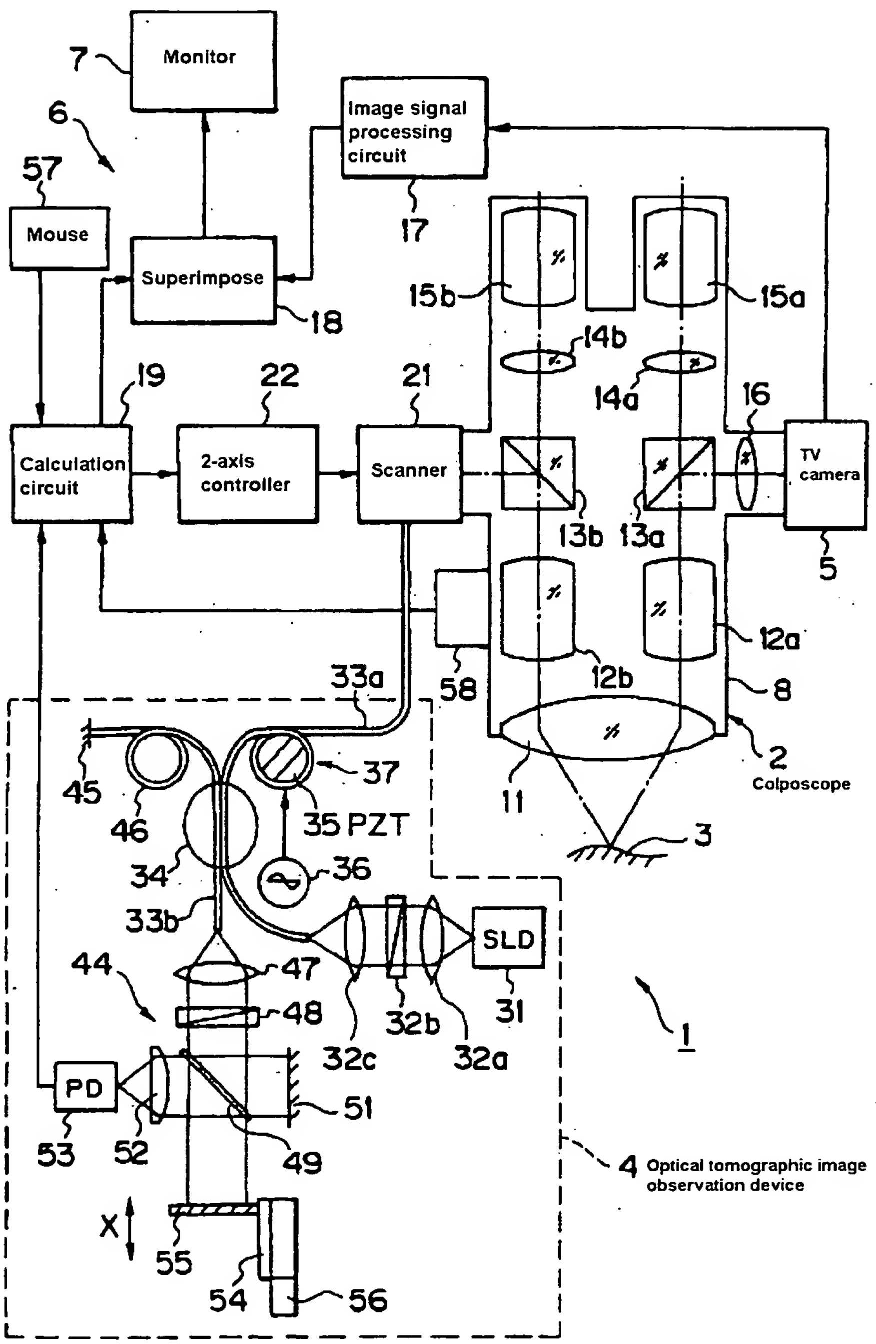


Fig.1




58 Magnification detector

Fig.8

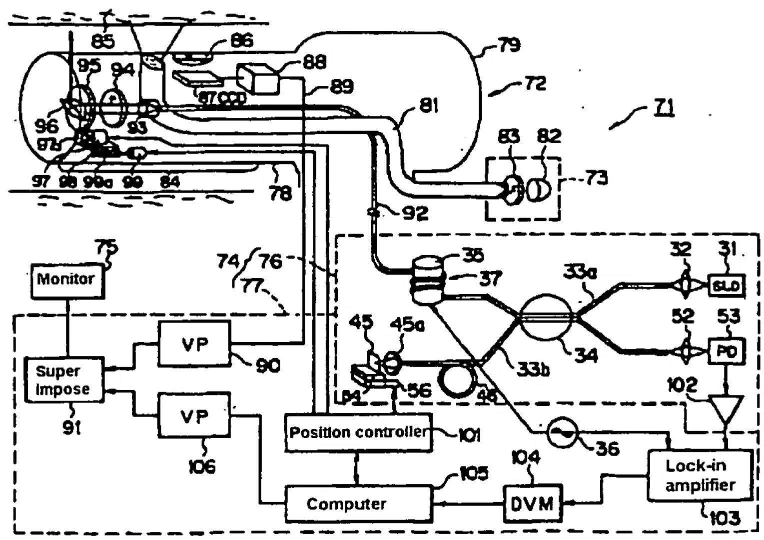



Fig.11

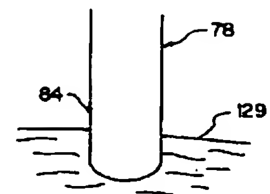


Fig.9

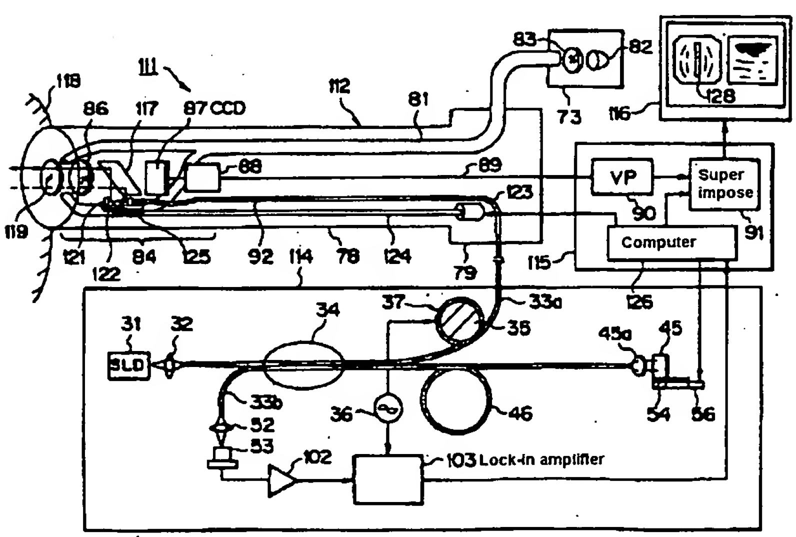
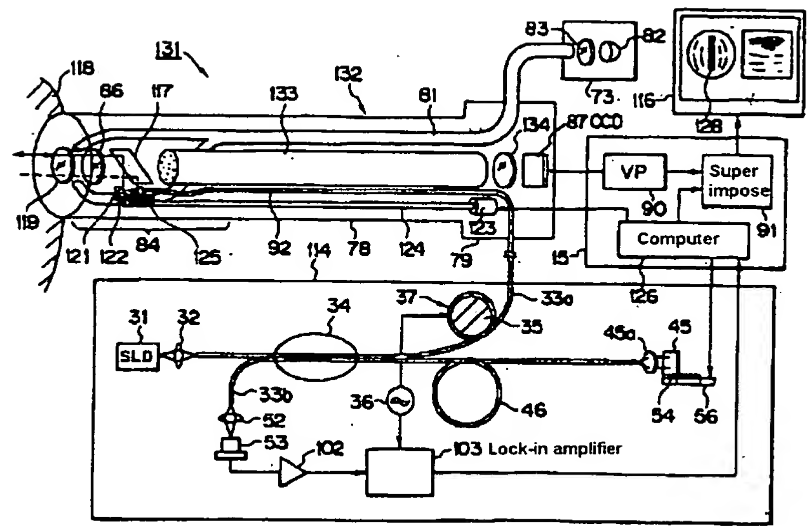


Fig.12



[Procedure Amendments]

[Filed on] March 12, 1993

[Procedure amendment 1]

[Title of document to be amended] Specification

[Item to be amended] 0053

[Method for amendment] Change

[Details of amendment]

[0053] The light reflected by the duct organ 85 is made incident onto the front end face of the optical fiber 92 through the prism 96, lens 94, SELFOC lens 93, and then made incident onto the front end face of the optical fiber 33a from the rear end face of the optical fiber 92a. Almost the half of this light is transferred to the optical fiber 33b by the coupler 34, and guided to the interference light detector side together with reference light reflected by the mirror 45 which is disposed opposite to the front end face of the optical fiber 33b.

[Procedure amendment 2]

[Title of document to be amended] Specification

[Item to be amended] 0077

[Method for amendment] Change

[Details of amendment]

[0077]

[Effect of the Invention] As described above, according to the

invention, since a observable surface image of visible light and a tomographic image of low-interference light of a body to be examined can be simultaneously displayed, the range of the affected tissue in the direction of the depth can be easily judged.

[Procedure amendment 3]

[Title of document to be amended] Specification

[Item to be amended] BRIEF DESCRIPTION OF THE DRAWINGS

[Method for amendment] Change

[Details of amendment]

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Fig. 1] Fig. 1 is a constructional view showing the optical tomographic imaging device of the first embodiment of the invention.

[Fig. 2] Fig. 2 is a perspective view showing the arrangement of the scanner.

[Fig. 3] Fig. 3 is an explanatory view showing that the monitor displays a tomographic image together with an image of an affected portion.

[Fig. 4] Fig. 4 is a drawing showing the TV probe in the modified example of the first embodiment.

[Fig. 5] Fig. 5 is a property diagram showing the spectrum properties of the dichroic mirror.

[Fig. 6] Fig. 6 is a drawing showing that an index corresponding to the range in which a tomographic image can be obtained is displayed on the monitor screen.

[Fig. 7] Fig. 7 is a sectional view showing the front end side of the TV probe in the modified example of Fig. 4.

[Fig. 8] Fig. 8 is a constructional view showing the optical tomographic imaging device of the second embodiment of the invention.

[Fig. 9] Fig. 9 is a constructional view showing the optical tomographic imaging device of the third embodiment of the invention.

[Fig. 10] Fig. 10 is a drawing showing the image display example of the monitor.

[Fig. 11] Fig. 11 is a drawing showing that observation is possible in the condition where the front end face of the insertable part is pressed against the tissue inside a body cavity.

[Fig. 12] Fig. 12 is a constructional view showing the optical tomographic imaging device of the fourth embodiment of the invention.

[Procedure amendment 4]

[Title of document to be amended] Drawing

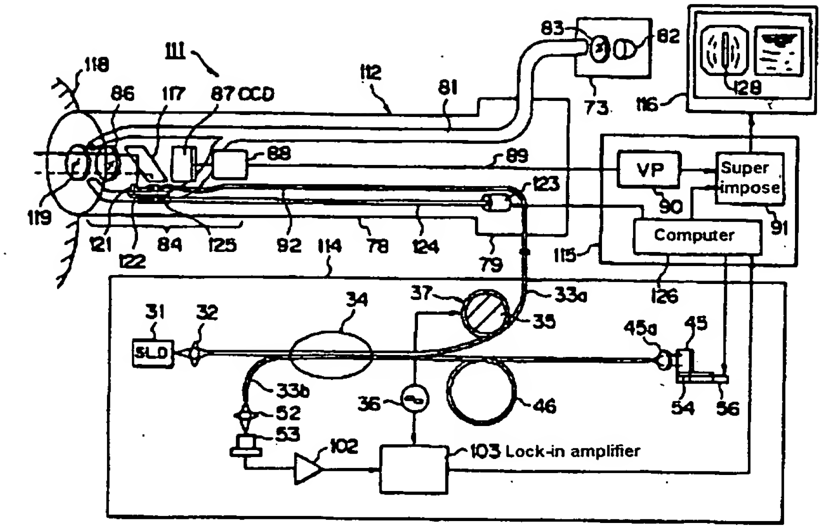
[Item to be amended] Fig. 9

[Method for amendment] Change

[Details of amendment]

[Fig. 9]

Fig.9



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